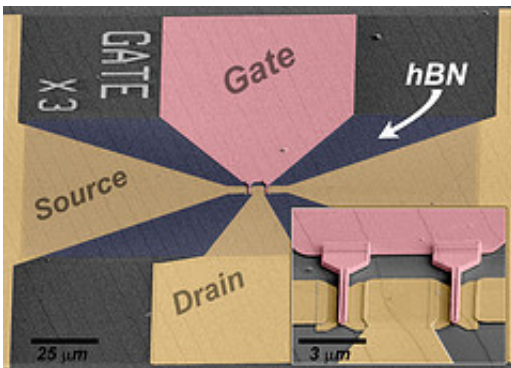


Graphene on boron nitride work may lead to breakthrough in microchip technology

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A team of Penn State researchers has developed field effect transistors using graphene and hexagonal boron nitride on a 75-millimeter wafer, a significant step toward graphene-based electronics.

(Phys.org) -- Graphene is the wonder material that could solve the problem of making ever faster computers and smaller mobile devices when current silicon microchip technology hits an inevitable wall. Graphene, a single layer of carbon atoms in a tight hexagonal arrangement, has been highly researched because of its incredible electronic properties, with theoretical speeds 100 times greater than silicon. But putting the material into a microchip that could outperform current silicon technology has proven difficult.

The answer may lie in new [nanoscale systems](#) based on ultrathin layers of materials with exotic properties. Called two-dimensional layered

materials, these systems could be important for [microelectronics](#), various types of hypersensitive [sensors](#), catalysis, [tissue engineering](#) and [energy storage](#). Researchers at Penn State have applied one such 2D layered material, a combination of [graphene](#) and hexagonal [boron nitride](#), to produce improved transistor performance at an industrially relevant scale.

“Other groups have shown that graphene on boron nitride can improve performance two to three times, but not in a way that could be scaled up. For the first time, we have been able to take this material and apply it to make [transistors](#) at wafer scale,” said Joshua Robinson, assistant professor of materials science and engineering at Penn State and the corresponding author on a paper reporting their work in the online version of the journal *ACS Nano*.

In the article, the Penn State team describes a method for integrating a thin layer of graphene only one or two atoms thick, with a second layer of hexagonal boron nitride (hBN) with a thickness of a few atoms up to several hundred atoms. The resulting bilayer material constitutes the next step in creating functional graphene field effect transistors for high frequency electronic and optoelectronic devices.

Previous research by other groups has shown that a common material called hexagonal boron nitride (hBN), a synthetic mixture of boron and nitrogen that is used as an industrial lubricant and is found in many cosmetics, is a potential replacement for silicon dioxide and other high-performance dielectrics that have failed to integrate well with graphene. Because boron sits next to carbon on the periodic table, and hexagonal boron nitride has a similar arrangement of atoms as graphene, the two materials match up well electronically. In fact, hBN is often referred to as white graphene. To be of more than academic interest in the lab, however, the hBN-graphene bilayer had to be grown at wafer scale – from around 3 inches (75 mm) to almost 12 inches (300 mm).

The Penn State team solved this problem by using a prior technique developed in their lab to produce a uniform, large-area, and high quality layer of epitaxial graphene suitable for high frequency applications. This “quasi-freestanding epitaxial graphene” was produced by attaching hydrogen atoms to the graphene in order to “passivate dangling bonds,” essentially flattening and smoothing the graphene film. The hexagonal boron nitride was then grown on a transition metal substrate using a chemical vapor deposition technique that is standard in manufacturing. The hBN was released from the substrate via one of several transfer processes and layered on top of the graphene on a 75mm wafer, marking the first integration of epitaxial graphene with hBN on a scale compatible with industry needs.

Building on their earlier work with epitaxial graphene, which had already increased transistor performance by two to three times, this research adds a further two-to-three-times improvement in performance and shows the strong potential for utilizing graphene in electronics, according to Robinson. In the near future, the Penn State team hopes to demonstrate graphene based integrated circuits and high-performance devices suitable for industrial-scale manufacturing on 100mm wafers.

“We use all standard lithography, which is important for nanomanufacturing,” Robinson added. In order to make a dent in the highly competitive microchip industry, a new material system needs to be compatible with current processing technology as well as offer a significant performance boost.

Boron nitride-graphene is one of several up-and-coming two-dimensional layered systems whose nanoscale properties are only beginning to be discovered. Dimensionality, according to Nobel Laureates Novoselov and Geim, is one of the most defining material parameters and can give rise to dramatically different properties according to whether the material structure is 0-D, 1-D, 2-D or 3-D.

Penn State is among the pioneers moving into what may prove to be a new frontier of materials science.

In addition to Robinson, the co-authors on the ACS Nano article are Michael Bresnehan, Matthew Hollander, Maxwell Wetherington, Michael LaBella, Kathleen Trumbull, Randal Cavalero, and David Snyder, all of Penn State. The work was supported by the Naval Surface Warfare Center Crane, and instrumentation support was provided by the National Nanotechnology Infrastructure Network at Penn State.

More information: “Integration of Hexagonal Boron Nitride with Quasi-freestanding Epitaxial Graphene: Toward Wafer-Scale High-Performance Devices” was published in online in the April 28, 2012, ASAP (as soon as publishable) edition of *ACS Nano*.

Provided by Pennsylvania State University

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